J. Phys. Ther. Sci.
27: 2955–2958, 2015

Original Article

Correlations among trunk impairment, functional performance, and muscle activity during forward reaching tasks in patients with chronic stroke

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Abstract. [Purpose] This study aimed to investigate the relationships among trunk impairment, functional performance, and muscle activity during forward reaching tasks in patients with chronic stroke. [Subjects and Methods] Twenty-three chronic stroke patients participated in this study. Trunk impairment and functional performance were evaluated using the Trunk Impairment Scale, Berg Balance Scale, Timed Up and Go Test, and 10-Meter Walk Test. All subjects were asked to perform 3 different forward reaching tasks (affected side reaching, forward reaching, and less-affected side reaching), and measurements were taken during these 3 tasks by using surface electromyography. Correlation analyses were performed to assess the relationships among trunk impairment, functional performance, and muscle activity during the forward reaching tasks. [Results] Spearman's correlation analysis revealed a strong, significant correlation between the Trunk Impairment Scale and functional performance, that was associated with balance and gait ability. During the 3 different forward reaching tasks, muscle activities of the less-affected lower extremity were significantly correlated with functional performance. [Conclusion] This study revealed the correlations among trunk impairment, functional performance, and muscle activity during forward reaching tasks in patients with chronic stroke and emphasized the importance of trunk rehabilitation.
Key words: Electromyography, Postural balance, Stroke

(This article was submitted May 11, 2015, and was accepted Jun. 18, 2015)

INTRODUCTION

Trunk muscles play an important role in balance and gait during functional activities[1)]. Voluntary contraction of trunk muscles counteracts the instability during distal limb movements and unpredictable perturbations[2, 3)]. These muscles also assist in spatial alignment of the trunk for proper movement[4)]. Trunk motor control is important during distal limb movement and is related to functional movements[5)]. Selective movements of the trunk are required to maintain the center of mass within the base of support and to maintain an upright posture during shifting of weight[6)]. All functional activities related to trunk motor control require good sensorimotor ability of the trunk[7)].

Trunk movement and balance ability are significant factors for functional independence in post-stroke patients[8)]. Trunk muscles stabilize the proximal body segments during several balancing activities in stroke patients[5)]. However, stroke impairs trunk control, which is required during weight-shifting and equilibrium reactions[9)]. Stroke patients exhibit decreased trunk motor control in all planes, with the frontal plane being the most affected[10)]. They are unable to maintain even weight distribution on both feet due to weakness of the trunk muscles and loss of trunk motor control ability[11)]. Stroke patients are unable to perform functional movements owing to the decrease in balance ability[12)]. Improvement in trunk motor control can therefore improve balance ability and performance of daily living activities[5, 13)].

Numerous studies on training interventions in stroke patients have focused on improving trunk motor control[14–16)]. Several studies have documented impairment of trunk motor control in stroke patients[5, 13, 17)]. Verheyden et al.[5)] compared the recovery of trunk motor control in 32 stroke patients. They found that the patients presented with mild-to-severe trunk impairment even 6 months after the stroke onset. Muscle weakness in stroke patients has been previously well documented by Karatas et al[4)]. Isometric and isokinetic contractions of the trunk muscles were found to be weaker in stroke patients than in healthy controls. In addition, electromyographic activities of trunk muscles on the affected side were delayed and reduced compared to those on the unaffected side during rolling from supine to side lying; and during voluntary flexion and extension of the trunk in stroke patients[18, 19)]. Trunk muscle strength has been shown to be positively correlated with balance and functional performance in stroke patients[20)]. A previous study

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by Verheyden et al.[13] that trunk exercises performed for an additional 10 hours improved trunk motor control ability in subacute stroke patients, and reaching exercises in sitting improved sitting balance, gait speed and peak vertical force on the paretic foot in chronic stroke patients[21]. Correlations among trunk impairment, functional performance, and muscle activity in patients with stroke are of special interest to physical therapists because numerous trunk exercises performed in the early stage of rehabilitation may improve the functional performance in the later stages. Thus, this study was designed to investigate the relationships among the trunk impairment, functional performance related to balance and gait ability, and muscle activities in the trunk and lower limbs during forward reaching tasks (FRTs) in chronic stroke patients.

SUBJECTS AND METHODS

Twenty-three subjects who were diagnosed with a single stroke more than six months ago and who were receiving physical therapy at the Rehabilitation Hospital in Seoul were recruited for this study. This study was performed in agreement with International Ethical Guidelines and Declaration of Helsinki and was approved by the Sahmyook University Institutional Review Board. All subjects signed an informed consent form and agreed to participate in the study after being explained the study purpose and procedures. The inclusion criteria were: (1) Mini-Mental State Examination-Korea score ≥24 points, (2) able to walk at least 10 m without assistive tools, and (3) Brunnstrom stage >3. Patients with lower motor neuron disease, cardiovascular disease, psychiatric problems, or orthopedic diseases were excluded from this study.

All subjects were evaluated by the same observer. Trunk impairment was evaluated using the Trunk Impairment Scale (TIS). The TIS evaluated trunk co-ordination and static and dynamic sitting balance. The maximal score for static sitting balance, dynamic sitting balance, and co-ordination were 7, 10, and 6 points, respectively. The total score was 0–23 points, with higher scores indicating better trunk performance. The validity, reliability, internal consistency, and measurement error of the TIS in stroke patients have been previously reported[6].

Functional performance related to balance and gait ability was evaluated using the Berg Balance Scale (BBS), 10-Meter Walk Test (10MWT) and Timed Up and Go (TUG) test. The BBS is used widely to evaluate balance ability and consists of items closely related to daily activities and prognosis in stroke patients. The maximal score of each subscale is 4 points for the 14 items, with a total score of 0–56 points. Higher scores indicate better balance. High intra-rater and inter-rater reliability have been reported in stroke patients[22]. The 10MWT and TUG test evaluate the time taken for walking. The reliability of timed gait tests in stroke patients has been reported previously[23, 24]. The TUG test is a quick measurement of balance, functional mobility, and movement ability. It assesses the time required to get up from a chair, forward walk for 3 m, turn around, and sit back down in the chair. The 10MWT measures the walking speed. The patients walked a total of 13 m, of which a distance of 1.5 m was covered at the start and end points, and the time required to walk the middle 10 m was recorded.

In the FRT, the patients were instructed to press 3 buttons (in 3 different directions) on a table at knee-height, and the distance was set at 10% of the subject's height. The 3 buttons were set such that 2 of these were at a 45° angle from the midline, and 1 was located straight ahead on the midline. The button on the affected side at a 45° angle from the midline comprised FRT 1, that on the midline comprised FRT 2, and that on the less-affected side at a 45° angle from the midline comprised FRT 3. The measurement tool used was the Telemyo EMG system (TelemyoDTS, Noraxon USA Inc., Phoenix, AZ, USA). Disposable bipolar surface EMG electrodes were attached 2 cm apart on each muscle. The patient's hair was removed, and the skin was sterilized with alcohol to reduce skin resistance before attaching the electrodes. The electrodes were placed bilaterally on the following 4 muscles of the trunk and lower extremities: erector spinae (ES), rectus femoris (RF), vastus lateralis (VL), and biceps femoris (BF)[25]. The MyoResearch XP Master Edition 1.07 software (Noraxon USA Inc., Phoenix, AZ, USA) was used for EMG analysis. The sampling rate was 1,000 Hz, and the band-stop frequency was 60 Hz. The signals were processed using root mean square after being full-wave rectified. Signal normalization was processed using submaximal voluntary isometric contraction, and the average submaximal voluntary isometric contraction value of each muscle was obtained from 3 repeated measurements. Muscle activities of the trunk and lower extremities were measured during an FRT performed in 3 directions.

SPSS software for Windows, version 12.0 was used for statistical analysis. Spearman's correlation analysis was used to determine the correlations among the TIS, BBS, TUG test, 10MWT, and muscle activities of the trunk and lower extremities during the FRT in 3 directions. The significance level was set at $p<0.05$.

RESULTS

Of the 23 subjects who participated in the study, 14 were males and 9 were females. The mean subject age was 59.39±9.22 y; mean height, 166.22±9.96 cm; and mean body weight, 62.83±11.30 kg. The median of the post-stroke period was 18.70 months, and the mean Mini-Mental State Examination-Korea score was 27.17. Eleven subjects were right hemiplegic, and 12 were left hemiplegic. With regard to stroke types, 11 subjects had experienced a hemorrhagic stroke and 12 an ischemic stroke; 10 subjects were Brunnstrom stage 3, 8 were stage 4, and 5 were stage 5.

Results of the correlation analysis among the results of the TIS, BBS, TUG test, and 10MWT in patients with stroke are summarized in Table 1. The TIS scores were significantly correlated with the BBS scores and with the results of the TUG test and 10MWT ($p<0.05$). The BBS scores and the results of the TUG test were significantly correlated with 10MWT ($p<0.05$). The Trunk impairment were significantly correlated balance and gait, and balance was significantly correlated with gait.

Results of the correlation analysis among results of the TIS, BBS, TUG test, 10MWT, and muscle activities of the

Table 1. Correlation between trunk impairment and functional performance in patients with stroke

	TIS	BBS	TUG	10MWT
TIS	-	0.529*	−0.426*	−0.516*
BBS	0.529*	-	−0.567*	−0.838*
TUG	−0.426*	−0.567*	-	0.674*
10M	−0.516*	−0.838*	0.674*	-

TIS: Trunk Impairment Scale, BBS: Berg Balance Scale, TUG: Timed Up and Go Test, 10MWT: 10Meter Walk Test.
*p<0.05

Table 2. Correlations among trunk impairment, functional performance, and electromyography during forward reaching tasks in patients with stroke

		TIS	BBS	TUG	10MWT
FRT 1	A.ES	0.168	0.035	−0.203	−0.060
	A.RF	−0.393	−0.197	0.403	0.312
	A.VL	−0.253	−0.256	0.487*	0.492*
	A.BF	−0.215	−0.357	0.483*	0.442*
	S.ES	0.223	0.071	−0.162	−0.101
	S.RF	−0.438*	−0.351	0.379	0.472*
	S.VL	−0.232	−0.595*	0.569*	0.651*
	S.BF	−0.428	−0.553*	0.815*	0.804*
FRT 2	A.ES	0.231	0.049	−0.229	−0.049
	A.RF	−0.334	−0.254	0.400	0.301
	A.VL	−0.232	−0.189	0.442*	0.439*
	A.BF	−0.181	−0.320	0.458*	0.417
	S.ES	0.300	0.029	−0.201	−0.095
	S.RF	−0.446*	−0.384	0.405	0.475*
	S.VL	−0.187	−0.541*	0.599*	0.622*
	S.BF	−0.368	−0.502*	0.755*	0.737*
FRT 3	A.ES	0.266	0.077	−0.322	−0.105
	A.RF	−0.411	−0.265	0.369	0.323
	A.VL	−0.162	−0.309	0.494*	0.510*
	A.BF	−0.194	−0.310	0.474*	0.427
	S.ES	0.333	−0.054	−0.144	−0.023
	S.RF	−0.497*	−0.420	0.471*	0.513*
	S.VL	−0.142	−0.385	0.487*	0.519*
	S.BF	−0.306	−0.352	0.622*	0.609*

FRT: forward reaching task, TIS: Trunk Impairment Scale, BBS: Berg Balance Scale, TUG: Timed Up and Go Test, 10MWT: 10Meter Walk Test, A: affected side, S: sound side, ES: erector spinae, RF: rectus femoris, VL: vastus lateralis, BF: biceps femoris.
*p<0.05

trunk and lower extremities during the 3 FRTs in patients with stroke are summarized in Table 2. The TIS scores were significantly correlated with RF activity during all FRTs on the sound side (p<0.05). The BBS scores were significantly correlated with the VL activity and BF activity during FRT 1 and FRT 2 on the sound side (p<0.05). The results of the TUG test were significantly correlated with the VL activity and BF activity during all FRTs on both sides; additionally, RF activity on the sound side was significantly correlated on FRT 3. The results of the 10MWT were significantly correlated with the VL activity during all FRTs on both sides, and with the RF activity and BF activity on the sound side. Additionally, the BF activity on the sound side was a significant correlation on FRT 1.

DISCUSSION

This study aimed to determine the correlation between trunk impairment and functional performance related to balance and gait. Our results clearly indicate that there is a correlation between these variables. Verheyden et al.[5]; have also supported similar findings. These results are of great clinical importance in stroke rehabilitation. Trunk impairment was found to be correlated with balance, and gait; therefore, any intervention that improves trunk performance will facilitate improvement in balance and gait in stroke patients.

Trunk stability is an essential core component of coordinated extremity movement, balance and performance of motor tasks. Trunk exercises for trunk stability also help to improve balancing abilities required for standing and walking in stroke patients[26]. Saeys et al.[16] reported that trunk control training improved dynamic balance, and trunk stability was essential for coordinated limb movements. Jung et al.[27] demonstrated that improved trunk control affected dynamic balance, walking speed, and symmetrical trunk movement during gait in stroke patients. The results of this study indicated a significant correlation among trunk impairment, functional performance, and muscle activity during forward reaching tasks in patients with chronic stroke.

This study also aimed to determine the correlation between functional performance and electromyographic activity during FRTs in patients with chronic stroke. The correlations between muscle activities of the trunk and lower extremities while performing 3 FRTs and functional performance were determined using the TIS, BBS, TUG test, and 10MWT. The results showed that the scores of the TIS and BBS had a significant correlation with BF activation during FRTs on the sound side. The results of the TUG test and 10MWT were significantly correlated with both lower extremities during FRTs.

Trunk muscle activation and strengthening are required for recovery of trunk motor control in stroke patients[28]. Extending the arm, as in reaching, improves trunk movement and trunk muscle activity in stroke patients[29]. In the present study, during FRT, the entire trunk helped extend the arm forward in the squatting position. Therefore, FRT affected the trunk and lower extremities on both sides in stroke patients. This study measured electromyographic activity in the trunk and lower extremity muscles.

Our results showed that functional performance is significantly correlated with lower extremity activity during FRT on the sound side. Most stroke patients shift their body weight over to the sound limb during standing and sitting. The affected limb is subjected to a lesser load than the sound limb. This study suggested that improvement on the TIS indicated lesser weight shift over to the sound limb.

The results showed that the results of the TUG test and 10MWT were significantly correlated with both lower extremities during FRTs. FRTs and simultaneous movement of the trunk and lower limb can improve symmetrical movements of the trunk and lower limb[29]. Hausdorff et al.[30] reported that asymmetric gait patterns can increase energy consumption. Symmetric gait patterns reduce the effort required and improve walking ability. This study suggested that walking ability affects the muscle activities of both lower limbs.

The results of this study indicated that trunk impairment and functional performance related to balance and gait are significantly correlated. A significant correlation was also noted between functional performance and electromyographic activity during FRTs in patients with chronic stroke. However, the number of subjects included in this study was insufficient for the results to be generalized; Future studies with a large sample size should assess the effect of trunk motor control training on electromyographic activity during FRTs and functional performance in stroke patients.

ACKNOWLEDGEMENT

This study was supported by Sahmyook University.

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